

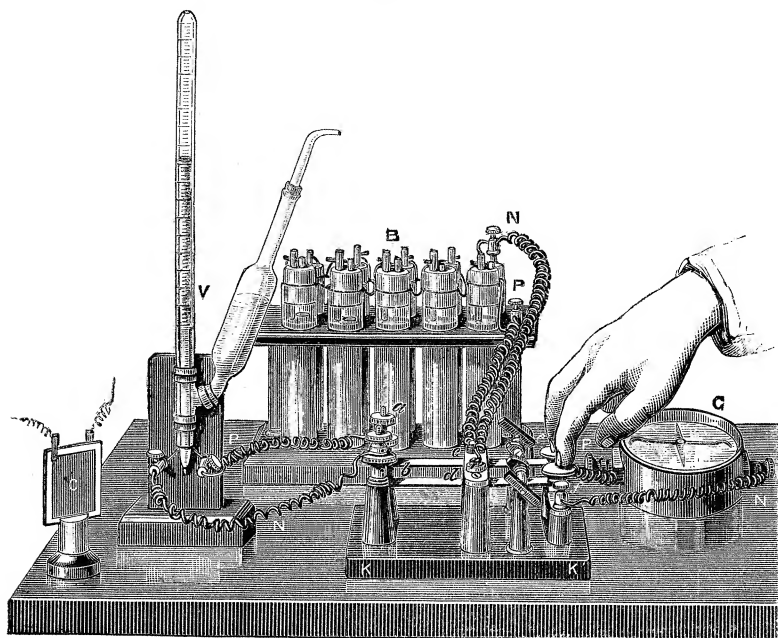
XI. "Experimental Researches on the Electric Discharge with the Chloride of Silver Battery." By WARREN DE LA RUE, M.A., D.C.L., F.R.S., and HUGO W. MÜLLER, Ph.D., F.R.S.
Received June 16, 1880.

SUPPLEMENT TO PART III.

The Electric Condition of the Terminals of a Vacuum-Tube after their connexion with the Source of Electricity has been broken.

The question has been mooted whether there is a polarisation of the terminals of a vacuum-tube after the discharge through it has been interrupted by breaking connexion between it and the source of electricity. This question we understand in the sense—does there exist a *chemical* polarisation as is the case for instance with the terminals of a voltameter under similar circumstances? It is evident that if a polarisation of this kind could be proved, the formula used for determining the tube potential ("Phil. Trans.," Part I, vol. clxxi, p. 65) would no longer hold good.

FIG. 1.



The problem is by no means easy of solution, and it has engaged our attention for the last five months. We believe, however, that the few

experiments we are about to describe, and which we select from a long series, will show that there is really no such polarisation of the terminals.

We will first take the case of the voltmeter; the arrangement of the apparatus employed in our experiments is shown in fig. 1, where $K K'$ represent a special key for breaking connexion between any piece of apparatus and the battery, B , and connecting it afterwards instantaneously with a galvanometer, G . The terminals of the battery are attached respectively to the screw-clamps, c and d , carried by an ebonite bar, supported on two ebonite columns, touch-points in metallic contact with c and d , pass through this bar, so that when the brass springs, ae and bf , are allowed to rise and press against these touch-points, the battery is in metallic connexion with the screw-clamps, a and b , and any piece of apparatus attached to them, as, for example, the voltmeter, V . The voltmeter employed has a resistance of 20 ohms; its platinum electrodes are 2.5 inches long and 0.025 inch in diameter, and are separated 0.25 inch; it is charged with dilute pure sulphuric acid in the proportion of 1 volume of acid, sp. gr. 1.84, to 8 volumes of water. When the springs are suddenly pressed down by the fingers placed on the ebonite disks, e and f , the connexion is broken between the voltmeter and the battery, and it is connected instantaneously with the galvanometer, G . The galvanometer actually employed was not that shown in the figure, but a Thomson galvanometer, whose constant, $C, = \frac{1 \text{ volt}}{1 \text{ megohm}} = 1,874$ scale divisions. On connecting a

battery of 10 chloride of silver cells with the voltmeter for a minute or less, and then suddenly pressing down the springs e and f , there was a deflection to the left, say, of more than 1,000 scale divisions, although the $\frac{1}{9.9}$ shunt was used to reduce the current through the galvanometer; therefore, the deflection without the shunt would have been more than 1,000,000 divisions. By comparing this deflection with that produced by a half microfarad condenser, charged with 240 cells, it was ascertained that the deviation produced by the voltmeter was equivalent to that of 111 microfarads.

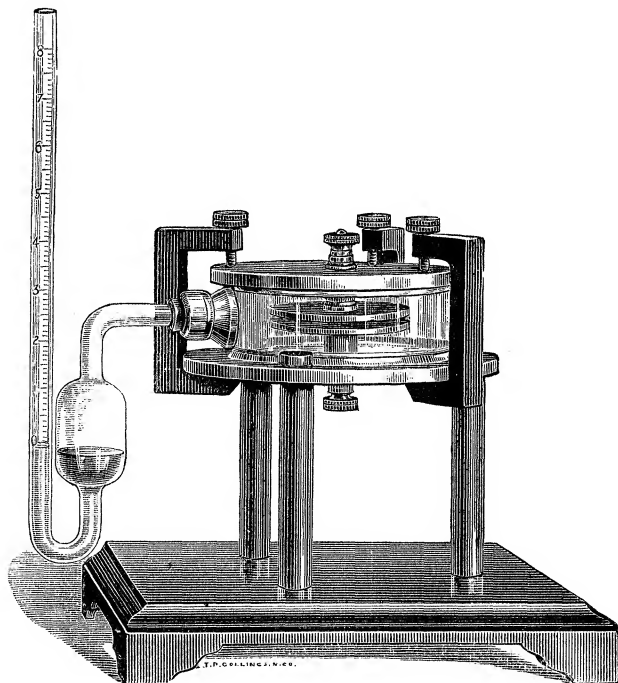
The small condenser shown at C , fig. 1, was substituted for the voltmeter; it is made of a thin plate of glass 2 inches square and 0.0115 inch thick; the tinfoil coatings being 1.5 inch square, its capacity was found to be 0.00055 m.f. When charged with 3,600 cells, and afterwards connected with the Thomson galvanometer through the $\frac{1}{9}$ shunt, by pressing down e and f , the deflection was 136.5 divisions to the left; this multiplied by 9.92, the value of the shunt was equivalent to 1,354 divisions.

The apparatus, shown in fig. 2, which was constructed for another object already described,* was connected with a and b ; it consists

* "Phil. Trans.," vol. clxxi, p. 76.

essentially of two disks, 3.1 inches diameter, placed 0.13 inch apart. The capacity of this apparatus, when used as an air-condenser, was determined, and found to be 0.000058 m.f. With 3,600 cells no discharge took place, and it merely charged up as a condenser. The deflection produced, when the keys *e* and *f* were pressed down, was (without shunt) 150 divisions, still to the left. It is evident, therefore, that the direction of the deviation throws no light on the question, for it is the same with the voltameter as with the condenser.

FIG. 2.

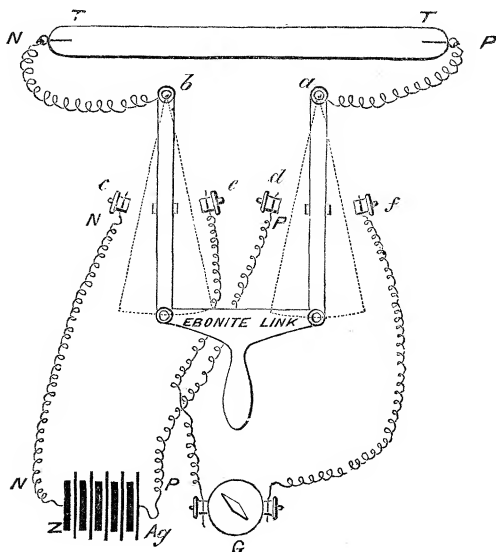


Tube 73, containing a residuum of acetylene, was now substituted for the air-condenser; it is 26.5 inches long and 1.5 inch diameter, the distance between the terminals 23 inches; this tube was connected with 3,600 cells, current 0.00681 W. The tube potential was found to be 2,980 cells, and its resistance 449,500 ohms. On pressing down the springs *e* and *f*, so as to break connexion with the battery and connect the tube with the galvanometer, there was a deflection of 11 divisions to the left, the same as before. The current was only $\frac{11}{1874 \times 1,000,000}$

$$= \frac{1}{170,000,000} \text{ W.}$$

The diagram, fig. 3, will illustrate the action of the special key, fig. 1. When the handle is moved to the left, the tube TT' is placed

FIG. 3.



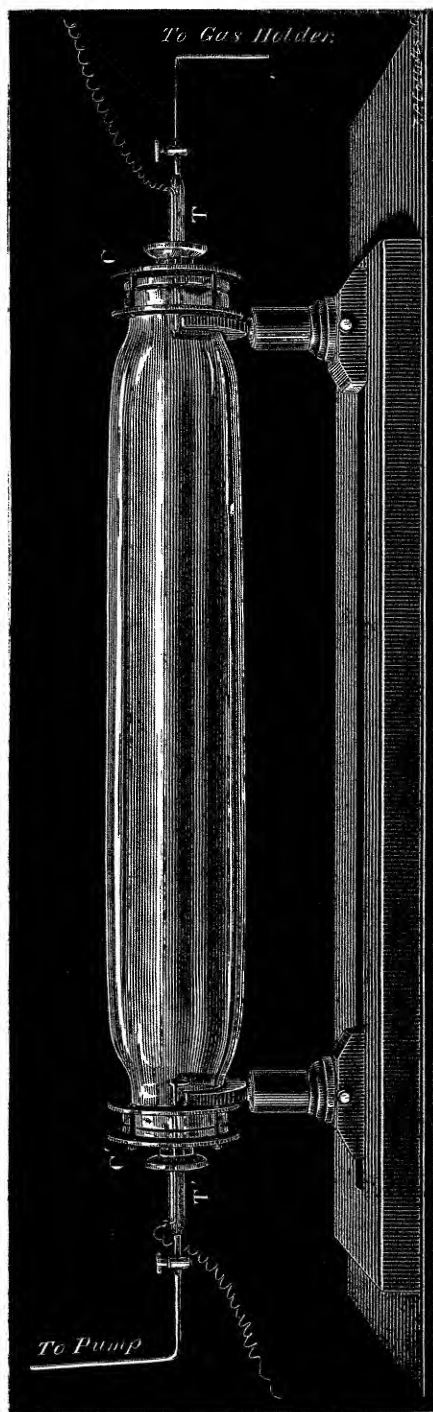
in metallic connexion with the battery, whose terminals are shown attached to *c* and *d* (this is equivalent to the springs being allowed to press upwards against *c* and *d*, fig. 1); when the handle is moved to the right, then the discharge of the battery through TT' ceases, and the terminals of the tubes N and P are connected with the galvanometer, the extremities of whose coil are attached to *e* and *f* (this is equivalent to pressing down the springs in fig. 1).

On another occasion with the same tube, No. 73, with a discharge from 2,400 cells, the deviation to the left on passing down *e* and *f* was 20 divisions.

Tube 199, with a hydrogen charge, was now substituted, fig. 4; pressure 2 millims., 2,632 M, 5,100 cells, current 0.01639 W. This tube has already been described;* it is 37 inches (94 centims.) long, and $5\frac{1}{16}$ inches (14.8 centims.) in diameter. The distance between the terminals, a ring and a straight wire, is 33.5 inches (85 centims.). In the first place the battery was connected direct to the galvanometer, the positive to *e* and the negative to *f* (that is, in the same direction as if the positive were attached to *c* and the negative to *d*). A short piece of wire was inserted between *e* and *f* as a shunt, and the $\frac{1}{999}$

* "Phil. Trans.," vol. clxxi, p. 104.

FIG. 4.



shunt was also used with the galvanometer, the direction of deviation was found to be to left, which it was desired to know.

On pressing down *e* and *f*, the deviation was to the left and only amounted to 2 divisions. On another occasion, at the same pressure, 3,900 cells, current 0.02925 W., the deviation to the left on pressing down *e* and *f* was from 3 to 5 divisions.

The same tube, with a charge of coal-gas, pressure 3 millims., 3,947 M, current 0.01705 W., deflection, on pressing down *e* and *f*, 7 divisions to left.

The same tube, with air, pressure 1.5 millims., 1,974 M, current 0.02728 W., on pressing down *e* and *f*, deviation 20 divisions. The deviation was, therefore, greatest with air; but if due to a chemical polarisation, it would have been *à priori* expected to be greatest with coal-gas, which is a mixture of decomposable molecules. The result of the experiments with tube 199 gave the following deviations:—

Hydrogen.	Coal-gas.	Air.
3	7	20

Again, tube 199, 2,400 cells, pressure 1 millim., 1,316 M, current 0.02456 W., deflection on pressing down the keys, 16 to left; with 1,500 cells no discharge, yet a deflection of 10 divisions to the left was produced on pressing down the keys. The deflection in the latter case being clearly due to a static charge.

Experiments were now made in air with the apparatus (already described *) shown in fig. 5, in order to obtain a vacuum vessel with larger terminals. The terminals are two disks a little over $4\frac{1}{4}$ inches (11 centims.) in diameter, and in the first instance were placed 3 inches (7.62 centims.) apart. Pressure 4.5 millims., 5,921 M, 2,400 cells, current 0.04366 W., deviation on connecting the disks with the galvanometer, 10 divisions to left.

With 1,200 cells, no discharge took place, but on connecting the galvanometer a deviation of 27 divisions to the left was, nevertheless, produced.

At a pressure of 20 millims., 26,316 M, with 3,900 cells, no current passed, but the deviation on connecting the galvanometer, was 66.6 divisions to the left.

The disks were now placed at a distance of 2 inches (5.08 centims.), the pressure being still 20 millims., and the battery 3,900 cells, the discharge now took place, current 0.03896 W., deflection on connecting galvanometer 8.5 to left.

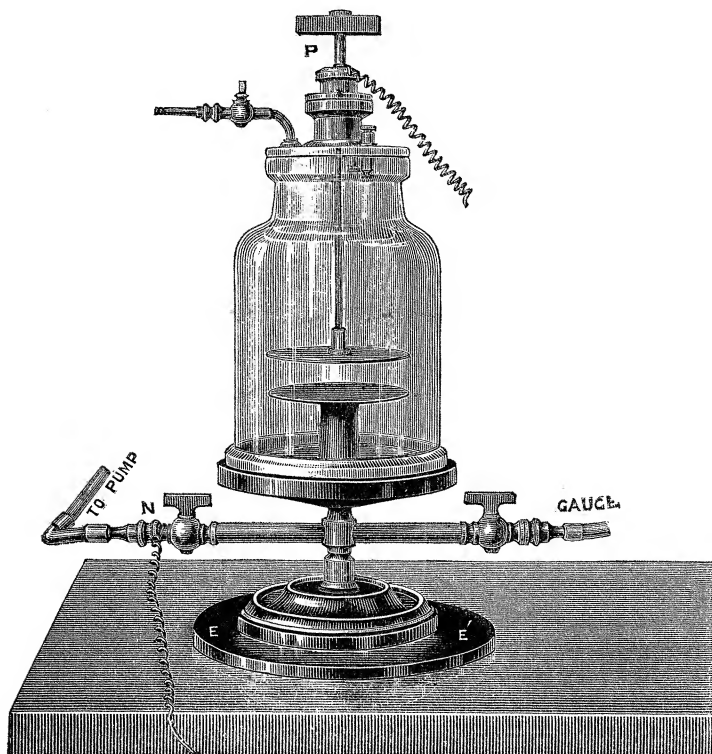
On reducing the battery to 2,400 cells, the discharge did not take place, but a deviation of 43 divisions was produced on pressing down *e* and *f*.

The disks were placed at 1 inch (2.54 centims.) apart, same pressure,

* "Phil. Trans.," vol. clxxi, p. 75.

with 3,900 cells, the current was 0.04201 W., deviation to left on connecting the galvanometer 13 divisions.

FIG. 5.



2,400 cells would not pass, but a deviation to the left of 47 divisions was obtained on connecting the galvanometer.

The following are the results of these experiments with the disks at various distances :—

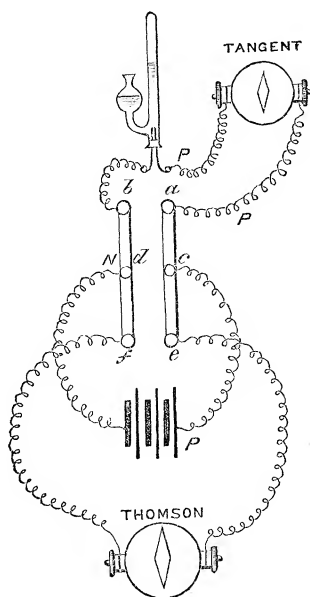
Distance, inches.	No. of cells.	Pressure. mm.	Current.	Deflection on con- necting galvano- meter, divisions.
3	1,200	4.5	did not pass	27.0
3	2,400	4.5	passed	10.0
3	3,900	20.0	did not	66.6
2	3,900	20.0	passed	8.5
2	2,400	20.0	did not pass	43.0
1	3,900	20.0	passed	13.0
1	2,400	20.0	did not pass	47.0

So that in every case when the discharge did not take place, the deflection, on connecting the terminals with the galvanometer, was the greatest.

If the fact which we have already pointed out be taken into account, that with a constant battery-potential, the difference of potential between the terminals of a vacuum-tube varies, in the same gas, according to the degree of exhaustion, it follows that as soon as a discharge takes place, the potential of the terminals will be lowered. We should therefore expect to find what the before-cited experiments indicated, namely, that the static charge of the terminals would be greater when no discharge takes place than after it has occurred, notwithstanding that a larger number of cells may have been employed in the latter case than in the former, for we have shown ("Phil. Trans.," vol. clxxi, p. 67), that a tube-potential may be only 430 cells, although the battery connected with its terminals is 11,000 cells.

We believe, therefore, that the experiments point conclusively to the deduction that the current obtained from the terminals of a vacuum tube, after having been disconnected from the battery, is solely due to a static charge and not to a *chemical* polarisation.

FIG. 6.



An experiment was made with the apparatus arranged as in fig. 6,

a tangent galvanometer being inserted in the circuit between the battery and the voltmeter, the $\frac{1}{999}$ shunt being used with the Thomson galvanometer.

No. of cells.	Current indicated by the tangent galvanometer.	Deflection of Thomson galvanometer, with shunt $\frac{1}{999}$, on pressing down <i>e</i> and <i>f</i> .	Divisions.
W.			
1	0.00000	 220 × 995.3*	218,930
2	0.00415	 765 „ 	761,380
3	0.03463	 984 „ 	978,820
10	0.14660	 990 „ 	985,150

On keeping down the keys *e* and *f* after the voltmeter had been connected with three cells, the deflection, which at first was 984 divisions, fell in—

1 minute to	110
2 minutes to	80
3 „	68
4 „	60
5 „	55
6 „	52
7 „	49

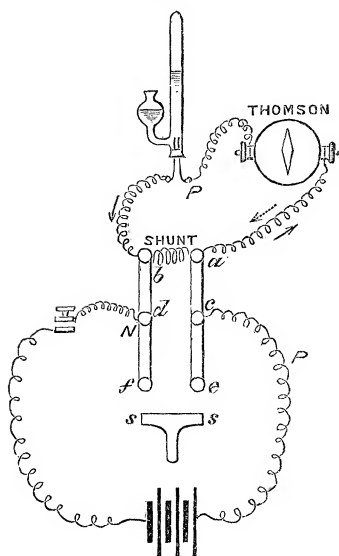
so that it was evident that a current was kept up by the voltmeter for a considerable time after the battery had been disconnected.

In order to render evident the direction of the current of polarisation of the voltmeter the apparatus was arranged as in fig. 7, that is, the Thomson galvanometer, with $\frac{1}{999}$ shunt, was inserted in the circuit between the battery and the voltmeter. An adjustable shunt was fixed between *a* and *b* to permit the greater part of the current to pass through it. A plate of metal, *ss*, was provided to slip under *e* and *f* to short circuit the return current through the galvanometer. The shunt which was found just sufficient to carry the major part of the current, and yet permit sufficient to traverse the voltmeter to produce a just visible evolution of gas, was 13 ohms.

On connecting the battery, the current was in the direction of the lower arrow, and the deviation 133 divisions say to the left; on pressing down the keys on to the metal slip placed under them to short circuit the current, after the battery had been disconnected, the return current was in the reverse direction, as shown by the upper dotted arrow, the deviation being 425 divisions to the right. Even without pressing down the keys on to the metal slip nearly the same deviation was obtained on disconnecting battery for the return current then traversed the shunt from *a* to *b*.

* The value of the $\frac{1}{999}$ shunt.

FIG. 7.



On substituting either the bell-jar, with disk terminals, or the tube 199 for the voltmeter, the deflection of the return static charge was in the same direction as the return current from the voltmeter, so that, as we before stated, no inference can be drawn from the direction of the current as to its being produced by polarisation or a static charge. We think, however, that we have shown conclusively that the effect in the case of a vacuum-tube is due to a static charge, and not to a polarisation of the terminals. We rest our opinion mainly on the fact that a greater deflection is produced, when the potential has not been lessened by a discharge through the tube, than that which occurs after the discharge has taken place, which, it had been surmised, might possibly produce a chemical polarisation.

XII. "On the Constants of the Cup Anemometer." By the Rev
T. R. ROBINSON, D.D., F.R.S., &c. Received June 13, 1880.

(Abstract.)

In a previous paper the author detailed experiments made by attaching anemometers to a whirling machine, and the conclusions to which they led. He was however doubtful of the accuracy of the method, and proposed one depending on the action of natural wind.

FIG. 1.

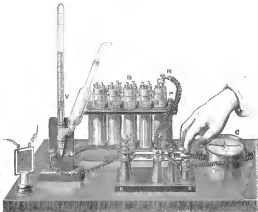


FIG. 2.

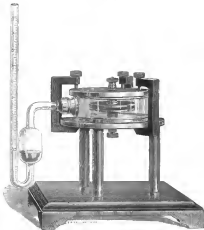
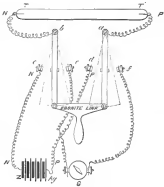


FIG. 2.



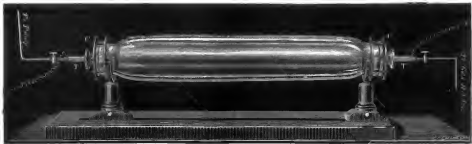


FIG. 5.



FIG. 8.

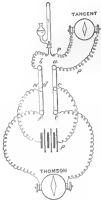


FIG. 7.

